

Markal-Times assessment of long term CO_2 emissions targets for France

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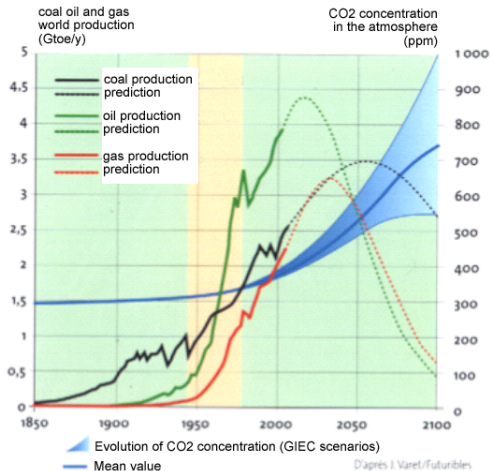
June 28, 2007
Stanford University
IEW 2007/ETP2008

Agenda

- 1 Motivations
 - International Environmental Commitments
- 2 Sensitivity analysis
 - The French paradigm
 - Methodology
 - Hypothesis
 - Low Carbon Scenarios
- 3 Prospective sensitivity analysis
 - Alternative nuclear future
- 4 Prospective sensitivity analysis
 - Transportation options

Environmental impacts

In order to cope with environmental impacts



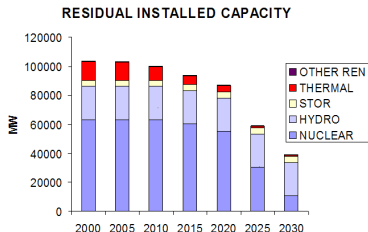
Environmental impacts

In order to cope with environmental impacts most countries are engaged in international agreements

- Kyoto protocol for 2012 horizon :
 - stabilize GHG emissions at 1990's level
 - France currently satisfies Kyoto targets
- Dividing by a factor 2 GHG worldwide by 2050 horizon induces
 - Factor 4 for France, Norway
 - Mitigation of 60% for UK
 - Mitigation of 80% for Germany

The specificities of the French electricity sector

- 1 Nuclear power replacement is the main driver for the future
- 2 French electricity production is dominated by nuclear power (79%)



- Replacement of existing capacities
- Future mix: Nuclear + Hydro + Fossil + Wind ?

Methodology

Through various exercises, two types of scenarios have been assessed

- Baseline or **business as usual** scenarios : based on the *trends*
 - Voluntary based or **low carbon society** scenarios : include hypothesis on *demand side management* and *energy efficiency*
- ⇒ All scenarios rely on **common hypothesis**

Common Economical hypotheses

- **Time horizon:** 2000-2050
- **Discount rate:** 5%

- **Fuel costs:**

	2005	2030	2050
oil \$/bbl	54	150	100
gas \$/Mbtu	8	11	15
coal \$/T	60	100	120

- **Transmission and Distribution Losses:** 7%
- **Trade:** Fixed 252 PJ (70 TWh) electricity exports then variable
- French energy Law commitment 13/07/2005
- **Renewable:** 21% of domestic demand in 2010
- **Restricted technologies options:** No CCS, No H_2 , No geothermal (HDR)

Low Carbon Scenarios

Low Carbon Scenarios include specific hypothesis on *Demand Side Management*

Residential sector:

- insulation (100% to 75% of 190 TWh)
- heat-pump dissemination

Transportation sector:

- improvement of engine efficiency
- mitigation of mobility

In order to assess the feasible level of mitigation for CO_2 emissions by 2050, alternative low carbon scenarios are assessed.

alternative low carbon scenarios

The sensitivity analysis evaluates

- 1 Alternative nuclear future
- 2 Alternative transportation technology options

associated with either

- **constraints** on the CO_2 emission level :
To avoid adjustments in the last periods alone, an emission path is specified.
- **taxes** on CO_2 emitted : euro/t CO_2

Alternative nuclear future

The alternative scenarios rely on common specific nuclear hypothesis:

- **Lifespan** for existing nuclear power plants : 40 years
- **Lifespan** for new REP nuclear power plants: 60 years (1 REP in 2012)
- **Nuclear specific costs**: nuclear-waste treatment costs (fuel price) and decommissioning costs (plant operation costs)

Three **Voluntary based alternative scenarios** are assessed :

Nuclear no limit scenario : No limit on future nuclear development

Limited nuclear scenario : 90 GW on the horizon by 2050

Feasable nuclear scenario : 65 GW on the horizon by 2050

Alternative transportation options

The alternative scenarios rely on common technologies options:
The vehicle mix is limited to

- conventional
- biofuel
- hybrid
- plug-in hybrid

Two Voluntary based alternative scenarios are assessed :

Only Liquid scenario : No gas

Reasonable scenario : gas + limited choice

Some results for low carbon scenarios

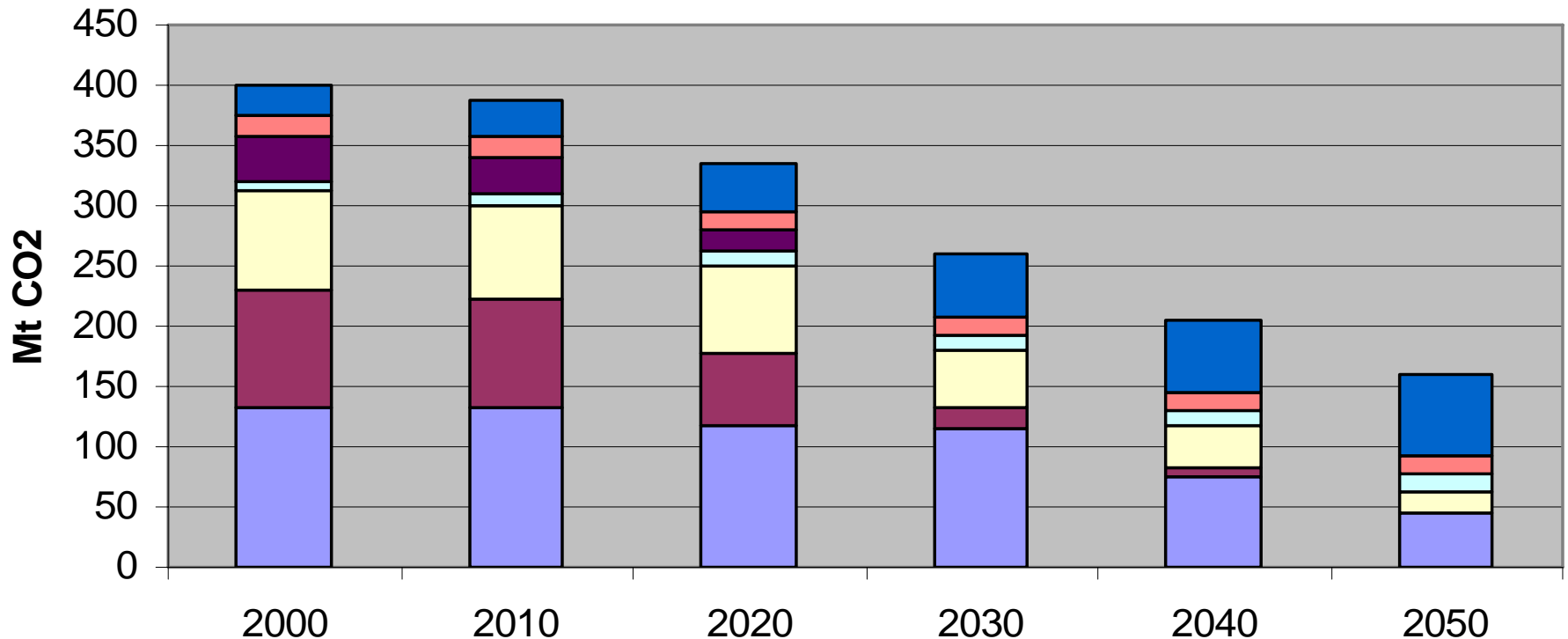
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(1) Low Carbon scenario

factor 4: Total CO₂ emissions

■ CO₂ emissions



■ Transp.
 ■ Res-Ter
 ■ Indus.
 ■ Agri.
 ■ Elec.
 ■ Raffin. & Prep. Coke
 ■ Transp. Intern.

(2) Low Carbon scenario

factor 4: Total CO₂ emissions

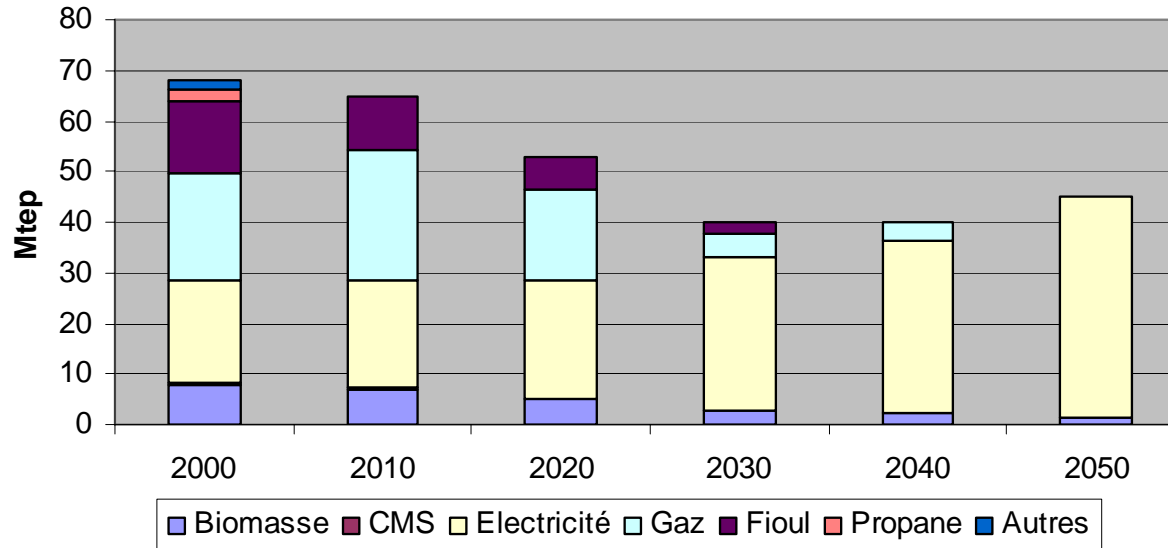
- CO₂ emissions

MtCO ₂	2000	2010	2020	2030	2040	2050
Transport	133	133	119	115	75	45
Res-Tertiaire	97	90	59	17	8	0
Industrie	82	76	74	49	33	17
Agriculture	8	10	11	12	13	14
Electricité	37	31	18	0	0	0
Raffin. & Prep. Coke	17	17	16	16	16	16
Transport Int.	25	31	40	52	60	66

(1) Low Carbon scenario

factor 4 : R/T final energy

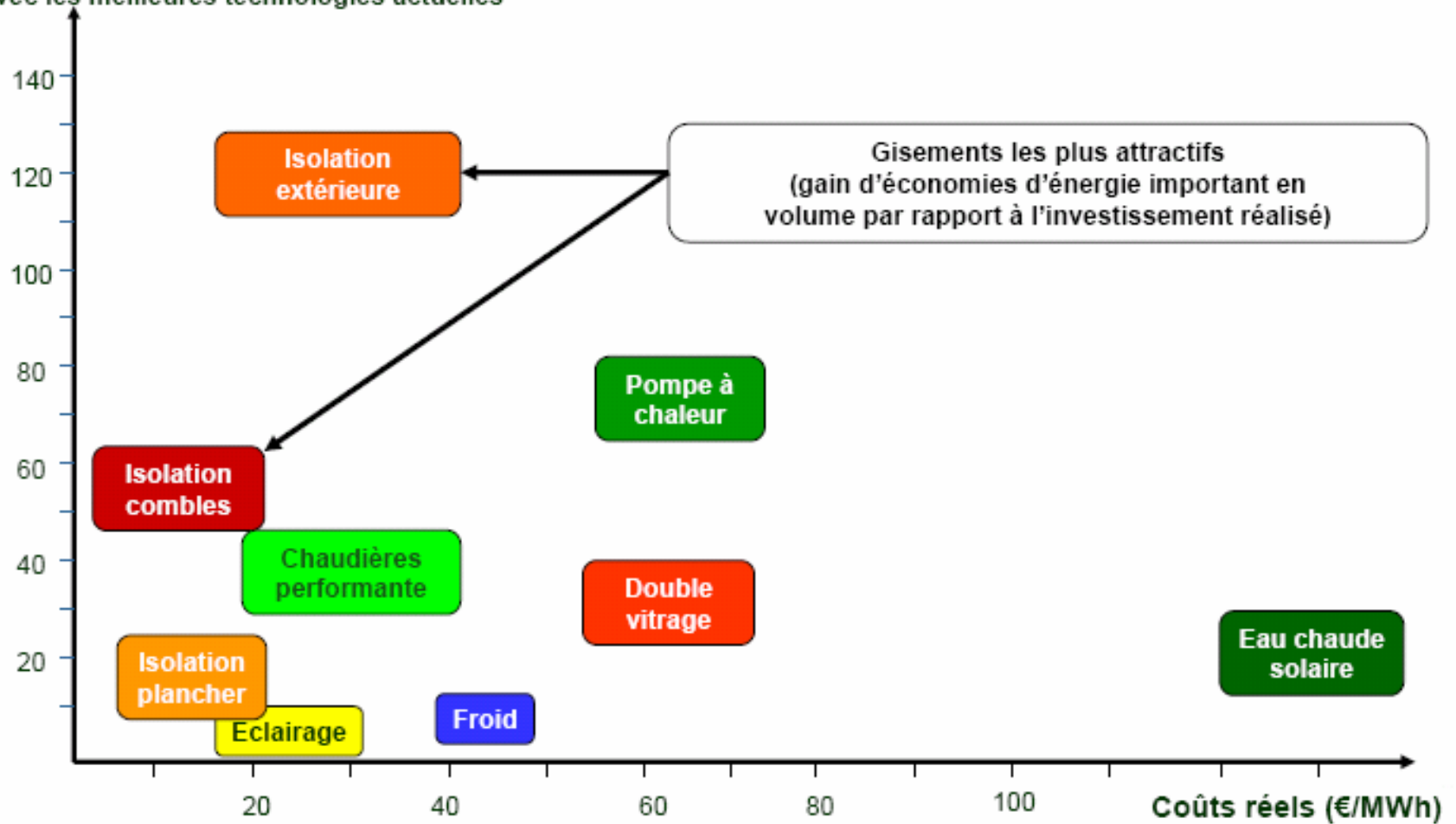
Energie finale: Résidentiel-Tertiaire



Mtep	2000	2010	2020	2030	2040	2050
Biomasse	7,7	7,1	5,3	2,7	2,2	1,3
CMS	0,6	0,3	-	-	-	-
Electricité	20,3	21,0	23,3	30,3	34,3	43,5
Gaz	21,3	25,9	17,9	4,9	3,6	-
Fioul	14,2	10,3	6,2	2,0	0,0	0,0
Propane	2,1	0,0	-	-	-	-
Autres	2,0	0,0	-	0,1	0,0	-
Total	68,2	64,7	52,7	39,9	40,1	44,9

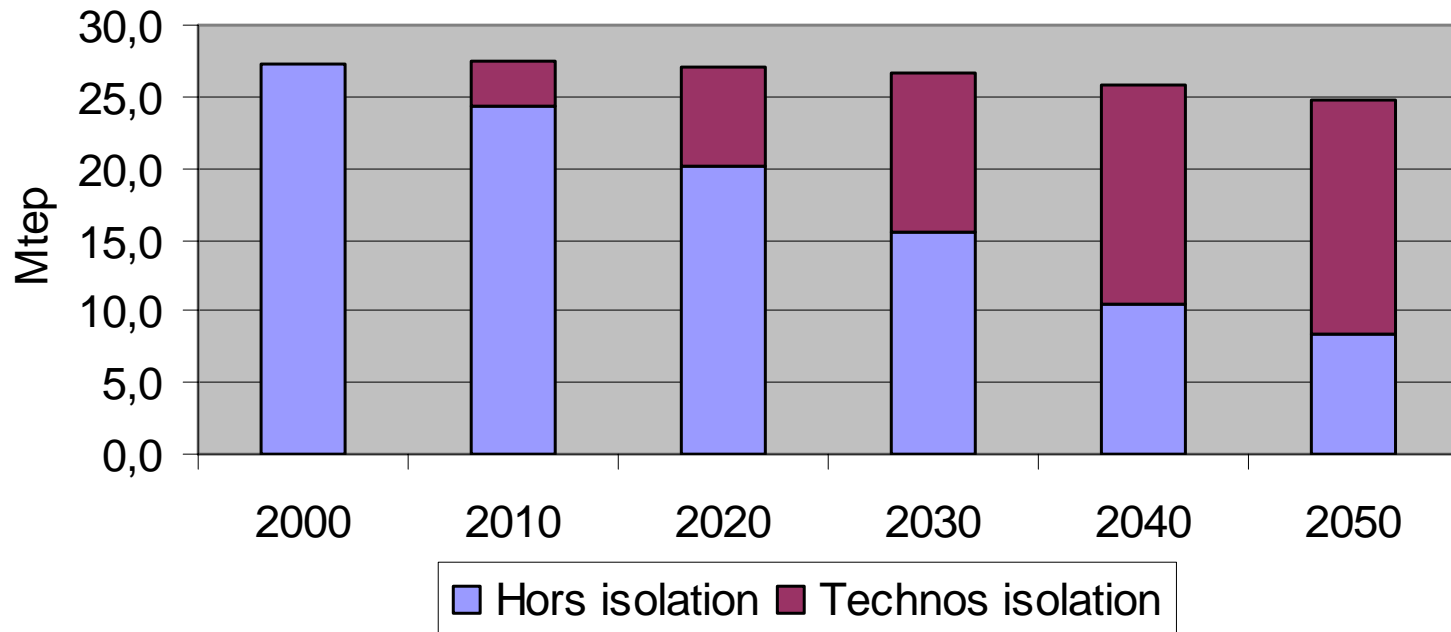
Insultaion in the residential/tertiary sector

Gisements théoriques en volume (TWh/an)
avec les meilleures technologies actuelles



- Residential : insulation potential from 100% to 75%

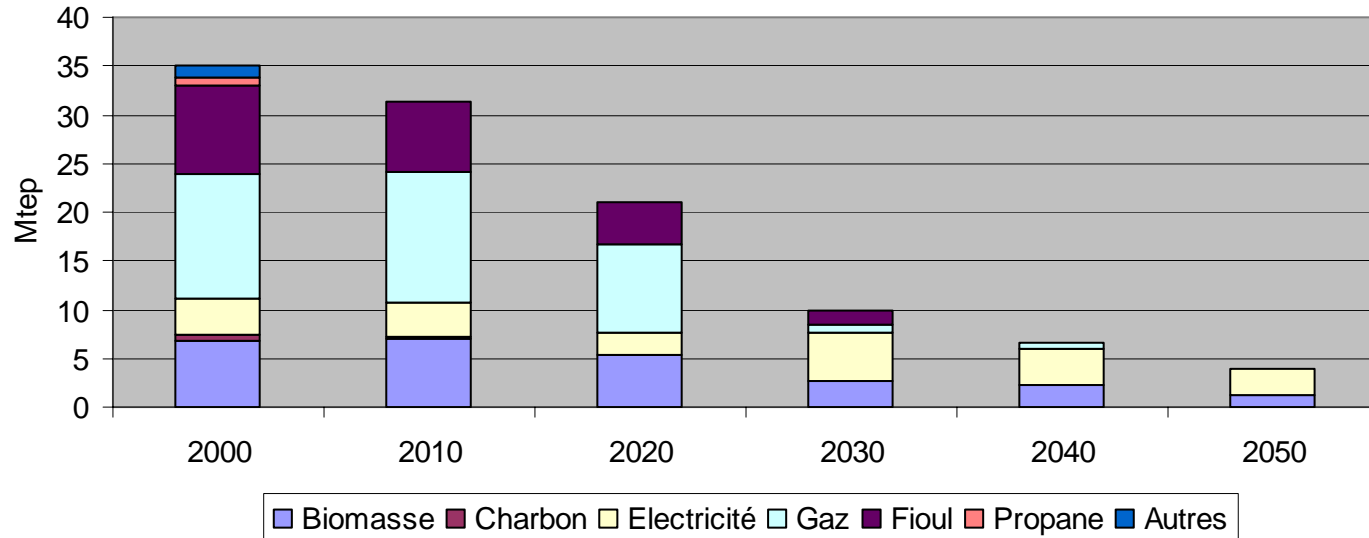
Demande utile de chauffage et isolation



(2) Low Carbon scenario

factor 4 : R/T heat final energy

ENERGIE FINALE POUR LE CHAUFFAGE

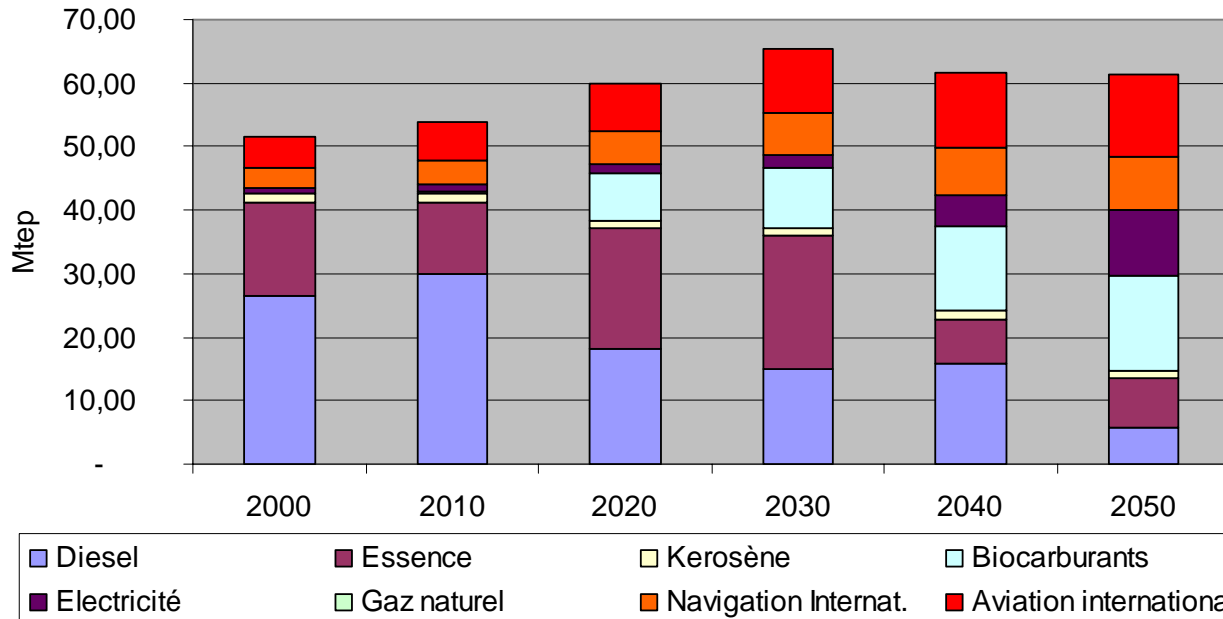


Mtep	2000	2010	2020	2030	2040	2050
Biomasse	6,9	7,0	5,3	2,7	2,2	1,3
Charbon	0,6	0,3	0,0	0,0	0,0	0,0
Electricité	3,8	3,5	2,4	5,0	3,8	2,7
Gaz	12,8	13,4	9,1	0,8	0,5	0,0
Fioul	9,1	7,2	4,3	1,5	0,0	0,0
Propane	0,8	0,0	0,0	0,0	0,0	0,0
Autres	1,3	0,0	0,0	0,0	0,0	0,0

(1) Low Carbon scenario

factor 4: Transport

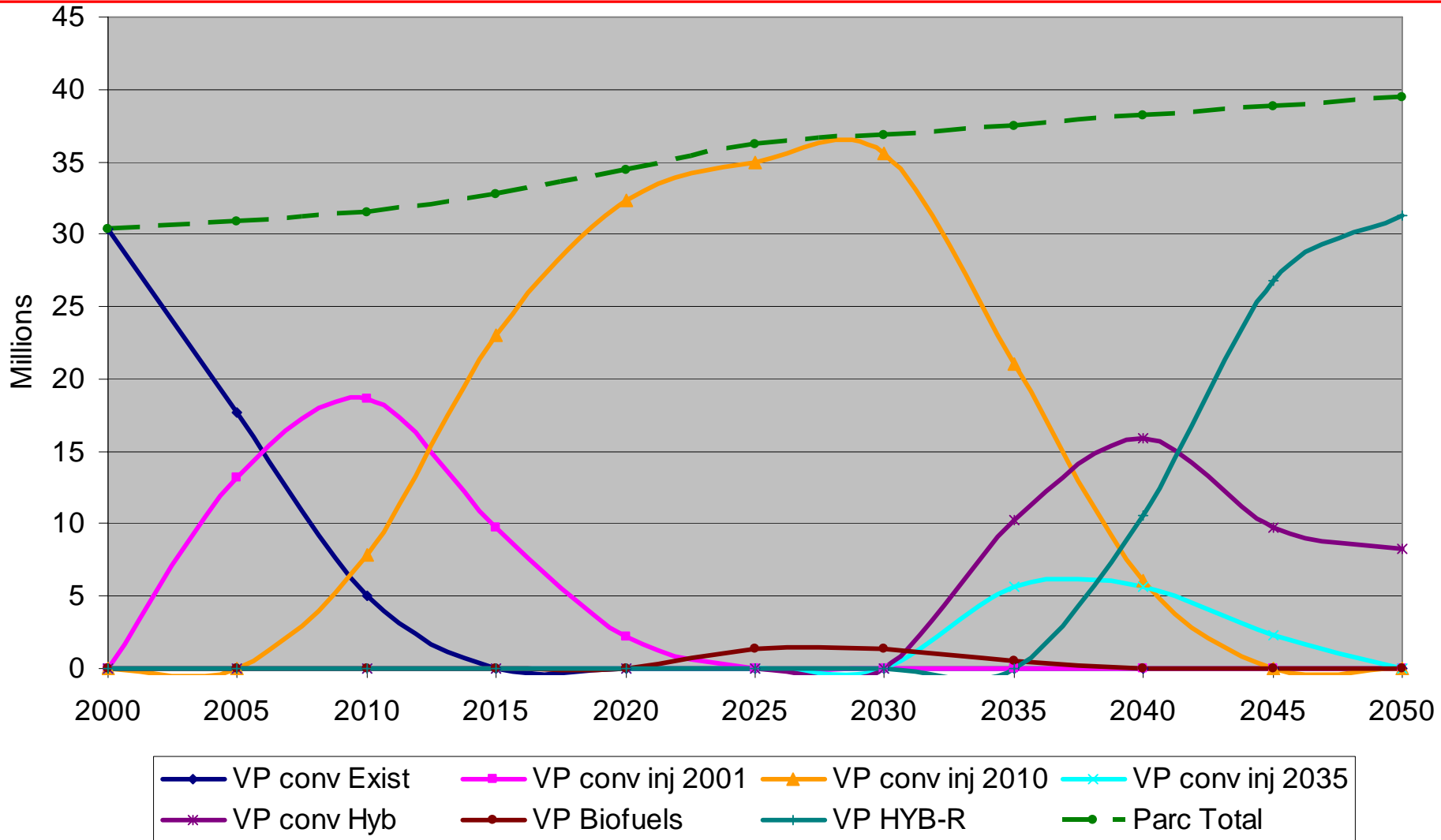
Energie Finale: Transport



Mtep	2000	2010	2020	2030	2040	2050
Diesel	26,5	30,0	18,2	15,0	16,0	5,7
Essence	14,7	11,2	18,8	20,9	6,9	7,8
Kerosène	1,4	1,4	1,3	1,3	1,2	1,2
Biocarburants	-	0,3	7,5	9,4	13,3	15,0
Electricité	0,8	1,1	1,4	2,0	5,0	10,5
Gaz naturel						
Navigation Internat.	3,2	3,8	5,3	6,6	7,4	8,4
Aviation : internationale	4,9	6,2	7,5	10,2	11,7	12,9

(2) Low Carbon scenario

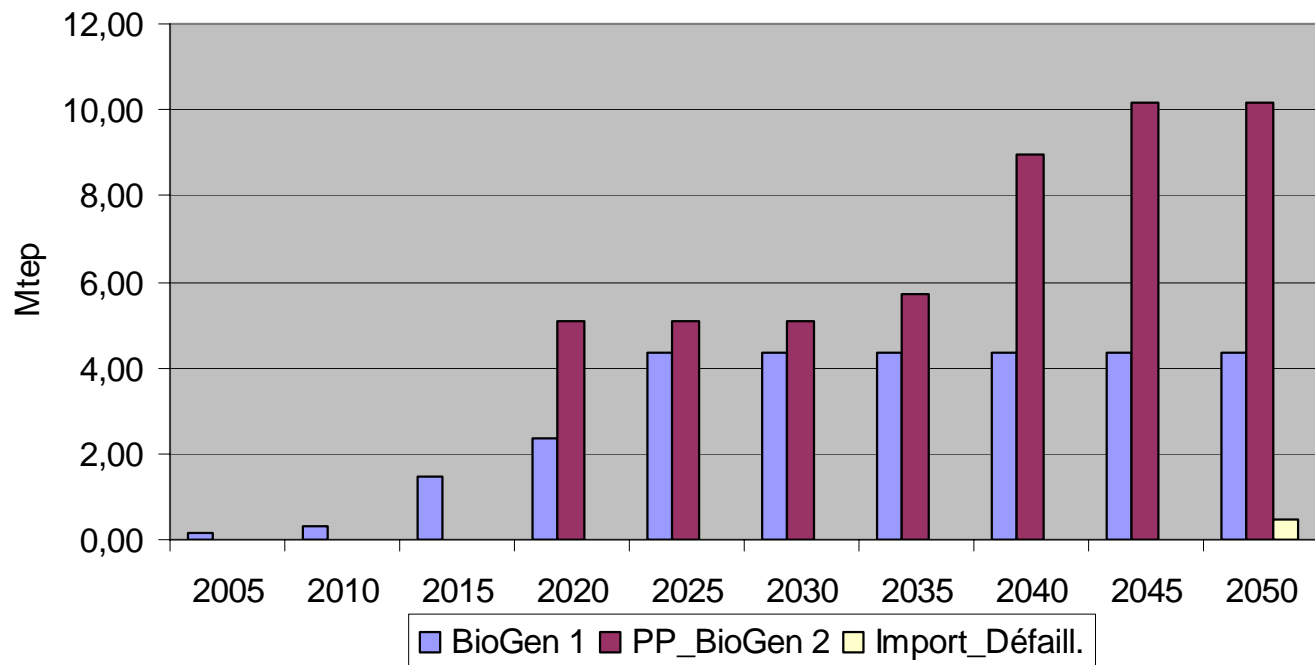
transportation: VP



(3) Low Carbon scenario

transportation: biofuels

- Biofuels production

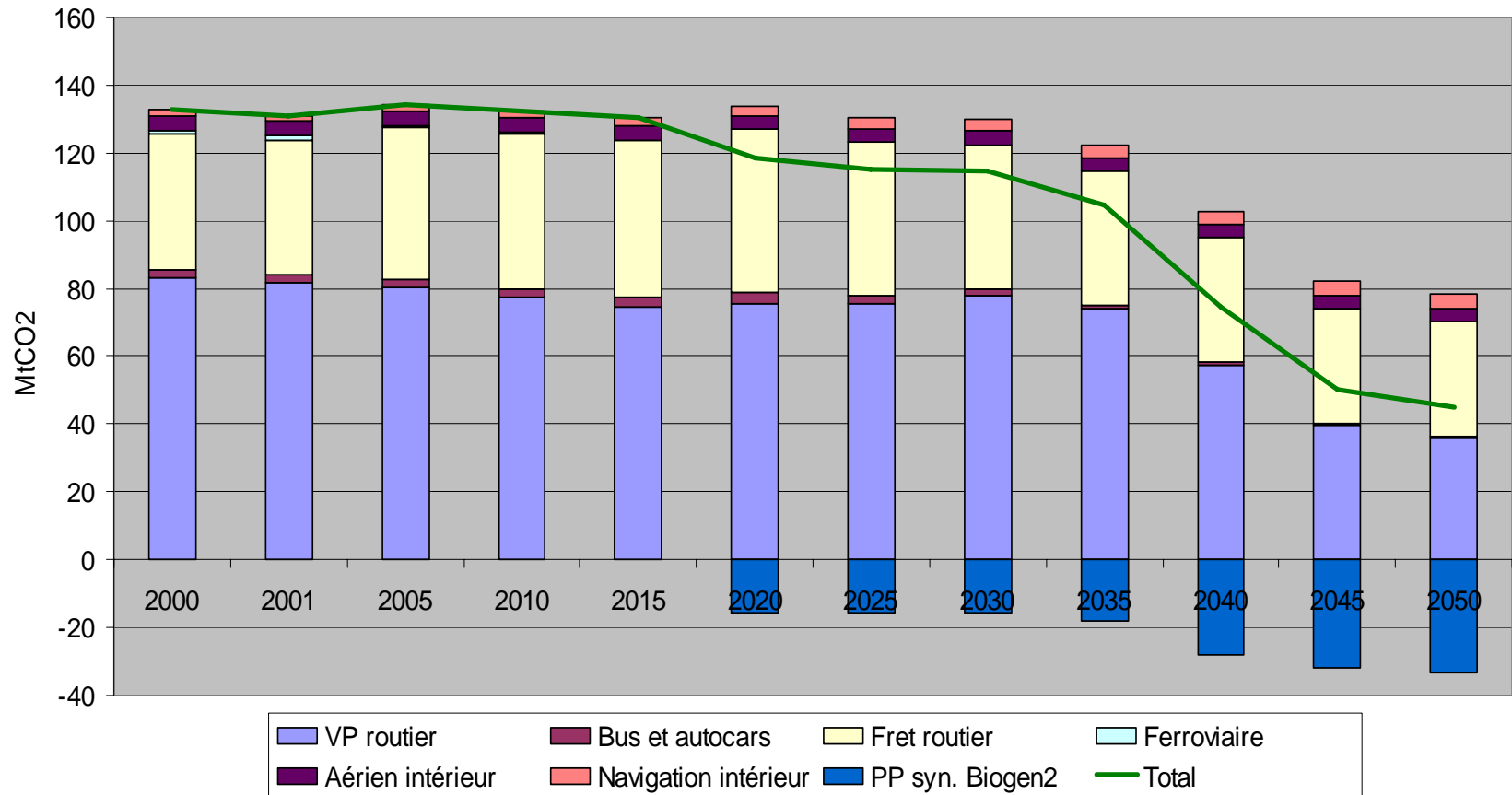


Mtep	2010	2020	2030	2040	2050
BioGen 1	0,33	2,36	4,33	4,33	4,33
BioGen 2_Prod Pétr	0	5,09	5,09	8,96	10,18
Import_Défaill.	0	0	0	0	0,45

(4) Low Carbon scenario

transportation: modal emissions

■ Transportation emissions by mode



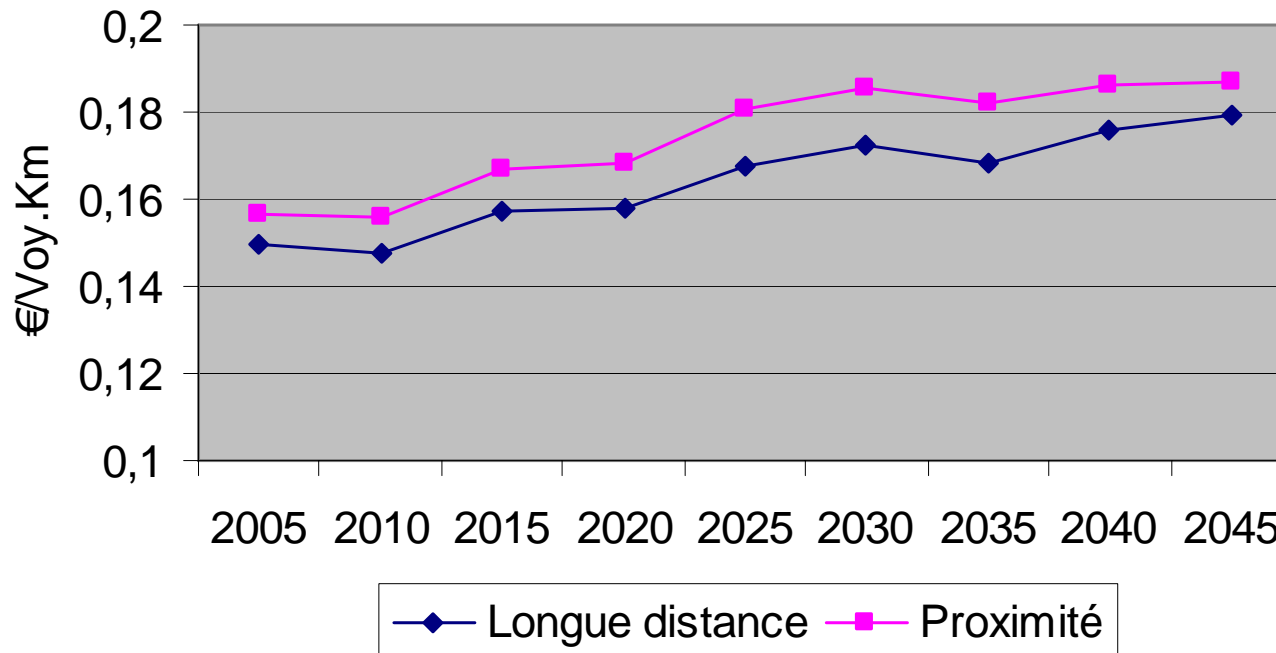
(5) Low Carbon scenario

transportation: modal emissions

■ Coût déplacement

= coût marginal demande de mobilité en c€/Voy.km

Coût marginal de la demande de mobilité

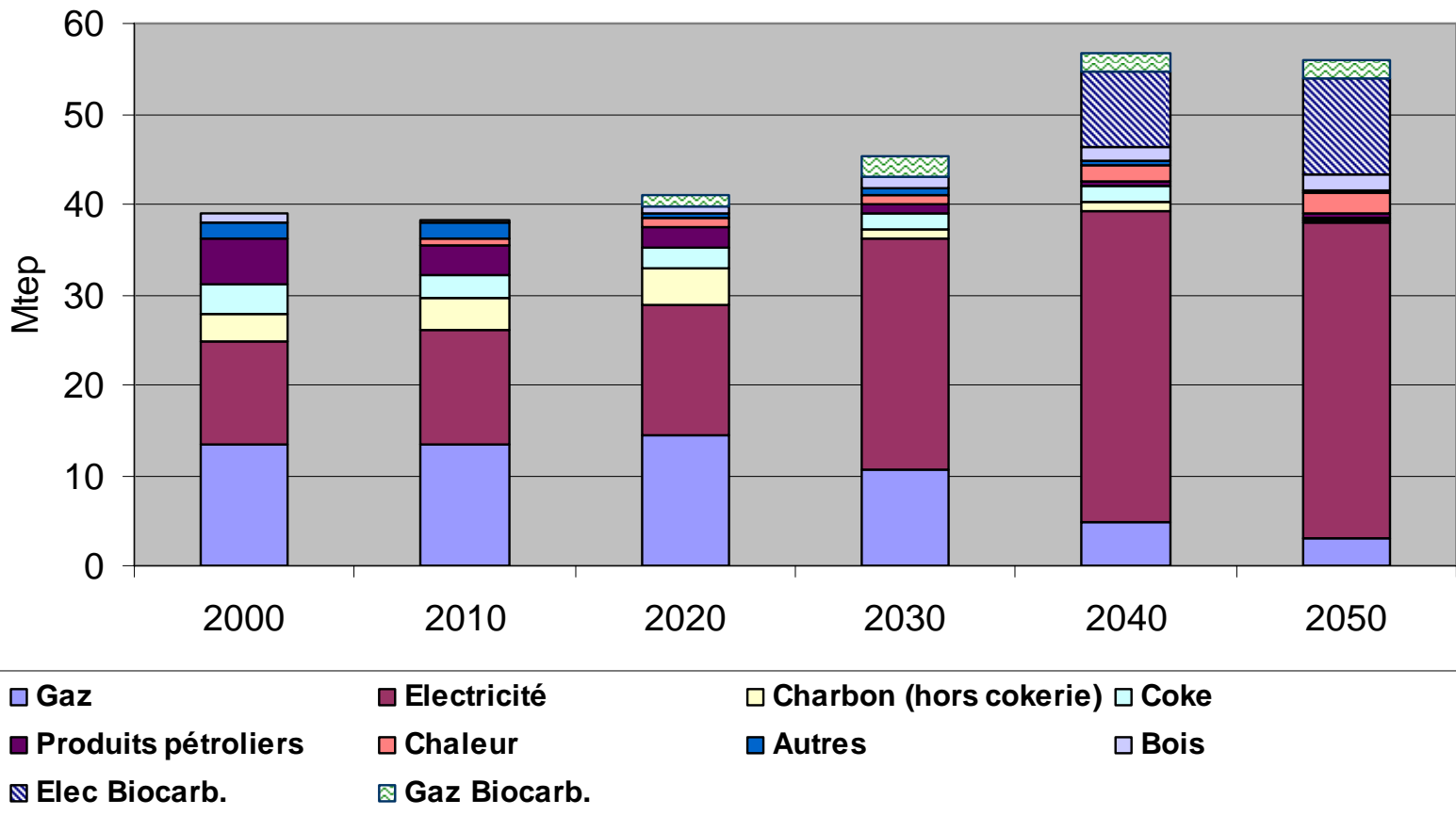


c€/Voy.Km	2010	2020	2030	2040	2050
Longue distance	14,8	15,8	17,2	17,6	323,7
Proximité	15,6	16,8	18,5	18,6	13,7

(1) Low Carbon scenario

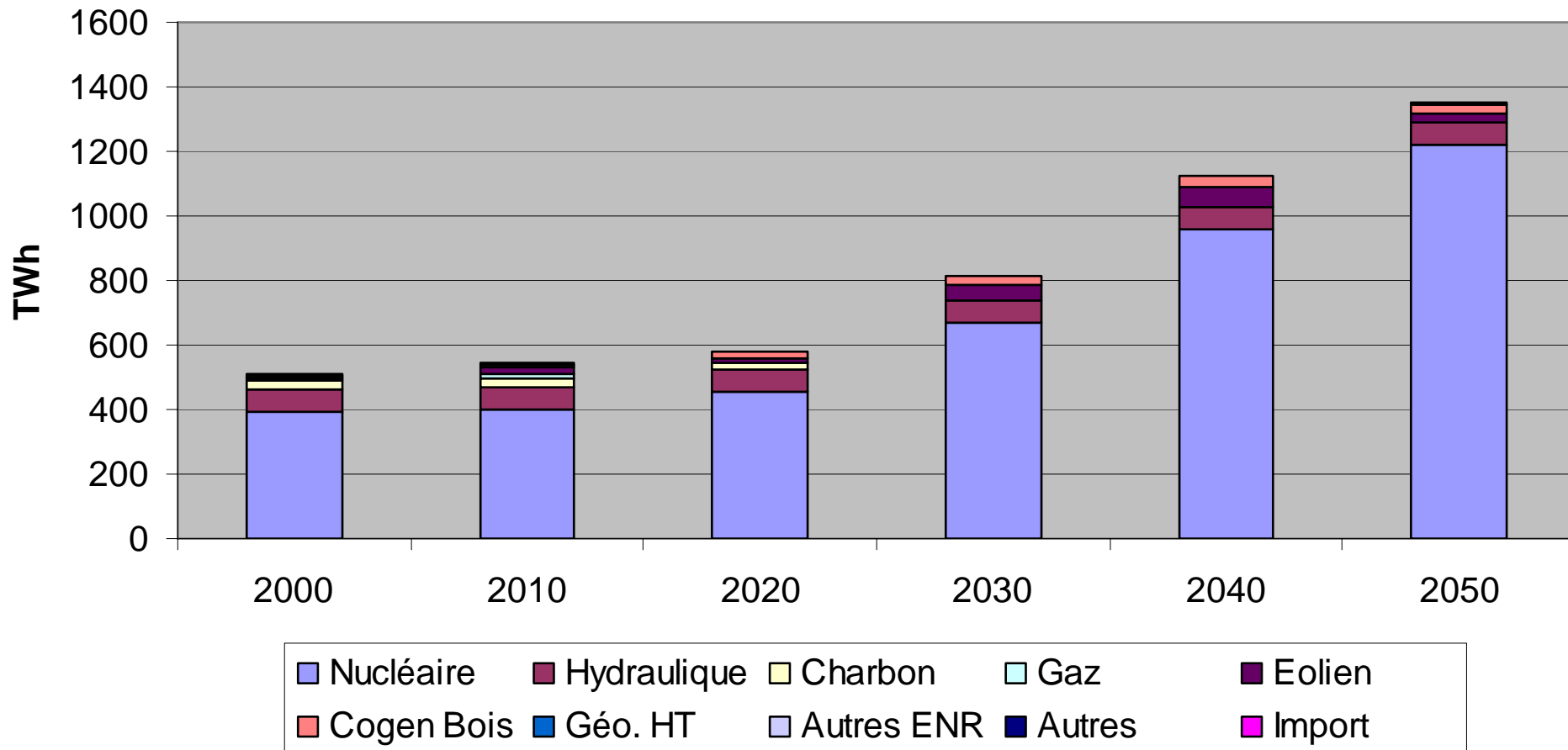
factor 4 : industry

- Final Energy: Industry (energy use)



Low Carbon scenario : electricity generation mix

Structure de la production électrique



Low Carbon scenario constrained by:

- factor 4 on all sectors

- factor 4 on all sectors
 - + factor 4 on transportation sector
 - + limited transportation technologies

- factor 4 on all sectors
 - + gaz vehicule technology

(1) 3 x4 comparison transportation CO2 emission

MtCO2	2000	2010	2020	2030	2040	2050
Low carbon.x4	133	133	119	115	75	45
Low carbon.x4 + x4Transport	133	133	107	74	52	36
Low carbon.x4+ Gaz Transport	133	133	118	113	74	34

(2) 3 x4 comparison : evolution of marginal abatement cost

- marginal abatement cost

€/tCO2	2010	2015	2020	2025	2030	2035	2040	2045	2050	Moyenne 2015-2045
Low carbon.x4	0	36	46	75	94	176	192	303	29214	132
Low carbon.x4 + x4Transport	0	37	42	43	54	67	81	97	5197	60
Low carbon.x4 + Gaz transport	0	36	45	74	96	107	187	311	2515	122

- marginal abatement cost

€/tCO2	2010	2015	2020	2025	2030	2035	2040	2045	2050	Moyenne 2025-2040
Low carbon.x4 + x4Transport	0	0	0	465	208	301	159	29098	24018	283

(3) 3 x4 comparison : installed capacity GW

GW installed	2000	2010	2020	2030	2040	2050
Low carbon.x4	113	116	116	140	174	195
Low carbon.x4 + x4Transport	113	116	131	145	167	196
Low carbon.x4 + Gaz Transport	113	116	116	139	161	196

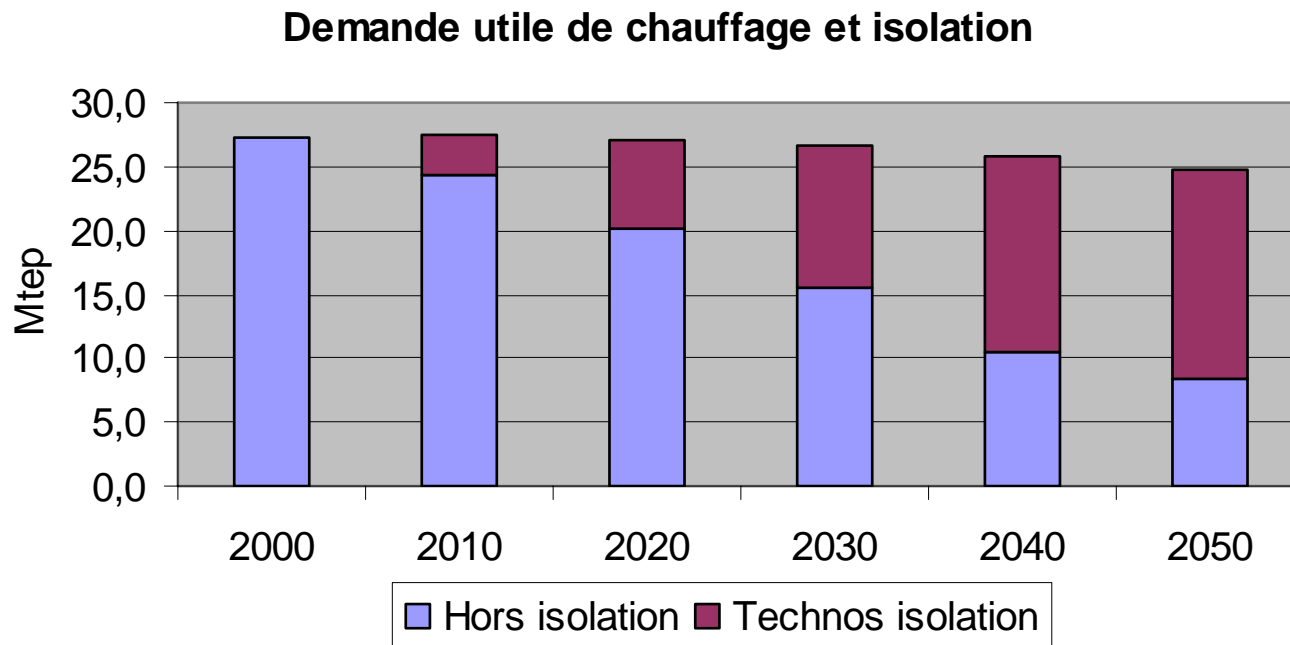
- With

GW Nuclear power	2000	2010	2020	2030	2040	2050
Low carbon.x4	63	64	69	88	122	155
Low carbon.x4 + x4Transport	63	64	79	92	115	156
Low carbon.x4 + Gaz Transport	63	64	69	87	109	154

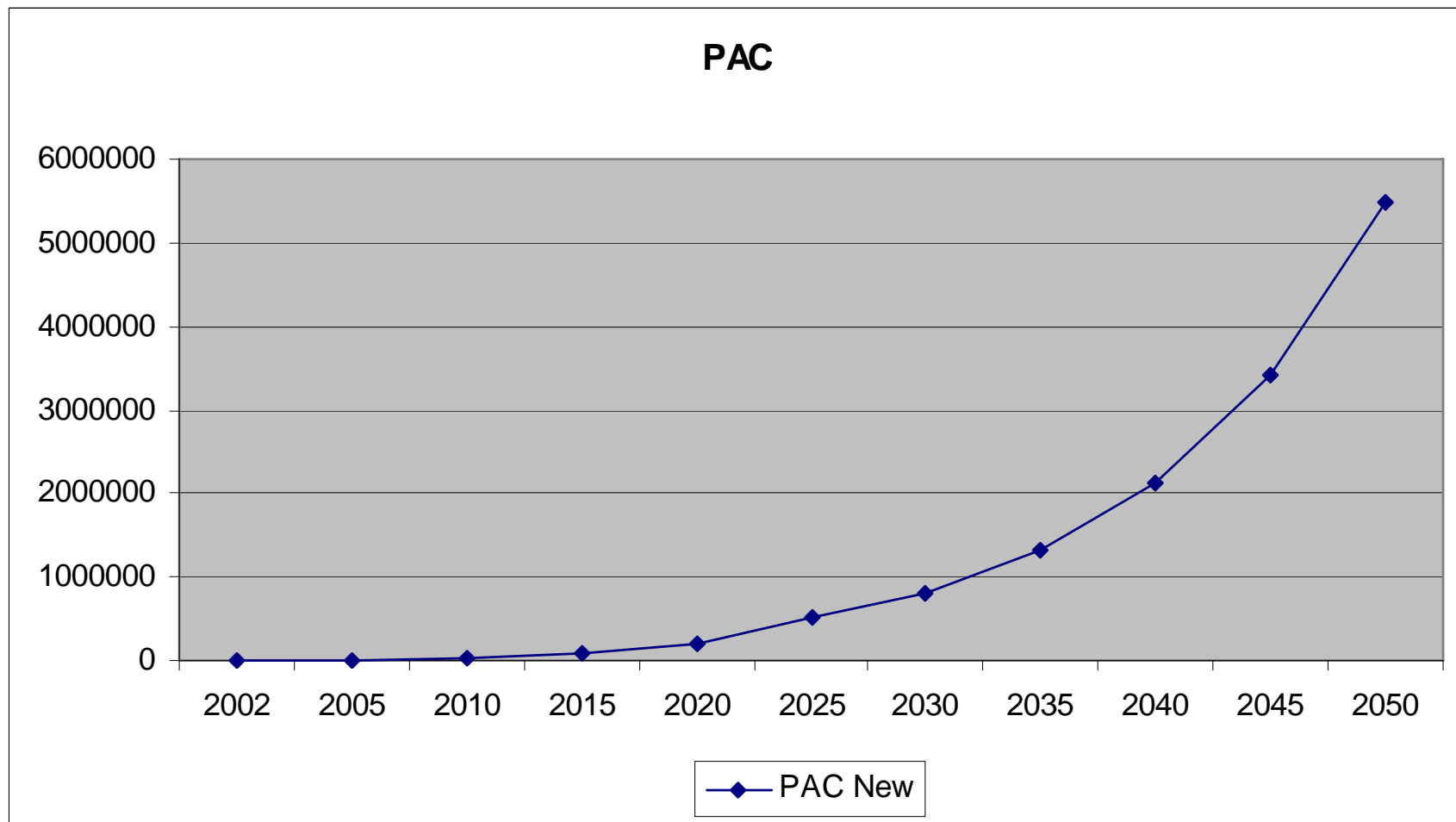
- 100 REP nuclear reactors in 30 years

limited nuclear (58 REP = 90 GW)

- Residential : insulation potential from 100% to 75%



Constraints on Heat pump growth hypothesis



Limited nuclear : Low carbon factor xx??

- Marginal cost of abatement evolution per ton of CO₂ avoided

Coût marginal €/tCO ₂	2015	2020	2025	2030	2035	2040	2045	2050
F4	43,6	82,4	489,8	1317,6	5094,3	9916,2	19699,9	29626,7
F3	45,0	110,2	455,7	505,3	1578,1	2442,9	5123,6	9926,9
F2	41,4	103,5	254,9	257,2	228,3	176,4	228,5	448,9

(3) Limited nuclear factor 2

power generation

- Mix of electric power generation

TWh	2000	2010	2020	2030	2040	2050
<i>NUC</i>	395,6	441,4	549,0	504,1	588,8	731,6
<i>HYD</i>	66,1	66,1	70,8	72,8	72,8	72,8
<i>CHARB</i>	27,0	18,0	0,0	0,0	0,0	0,0
<i>GAZ</i>	8,5	12,8	7,4	5,4	5,4	6,6
<i>FIOUL</i>	5,7	5,2	1,8	1,8	1,8	1,8
<i>EOLIEN</i>	0,1	16,3	33,2	27,0	16,3	16,3
<i>BOIS</i>	0,0	0,0	6,6	71,0	72,3	103,2
<i>DECHETS</i>	3,2	3,8	0,2	0,2	0,2	0,2
<i>AUTRES</i>						
<i>IND</i>	2,1	3,3	0,0	0,0	0,0	0,0
Total	508,4	566,9	669,0	682,3	757,6	932,5

(5) Low carbon scenario

(feasible nuclear) power exports

- Sensitivity to nuclear capacity constraint
 - It implies a variation in the exports to achieve F2

F2 exports (TWh)	2000	2010	2020	2030	2040	2050
Fixed elec export	70	69	69	69	69	69
Var. elec export	70	69	69	17	0	0

	2010	2015	2020	2025	2030	2035	2040	2045	2050
F2 var. export	0	39,8	129,2	634,9	880,2	313,5	1099	1848,8	5091,9
F2 fixed export	0	36,3	119,3	634,9	807,6	1715,6	2997,8	5509,6	8049,9
40% mitigations	0	41,5	129,3	320,5	1203,3	88,7	141,3	215,7	364,1

Electricity Consumption by sector triggered on exports hyp.

■ F2 with **fixed exports**

TWh	2000	2010	2020	2030	2040	2050
Résid-Tertiaire	236	283	356	329	341	396
Industrie	131	141	166	173	177	175
Transport	10	13	17	48	87	110
Agriculture	3	3	4	4	4	5
Total	379	440	543	554	609	686

■ F2 with **variable exports**

TWh	2000	2010	2020	2030	2040	2050
Résid-Tertiaire	236	283	358	330	352	411
Industrie	131	141	166	173	183	189
Transport	10	13	17	45	44	110
Agriculture	3	3	4	4	4	5
Total	379	440	545	552	583	714

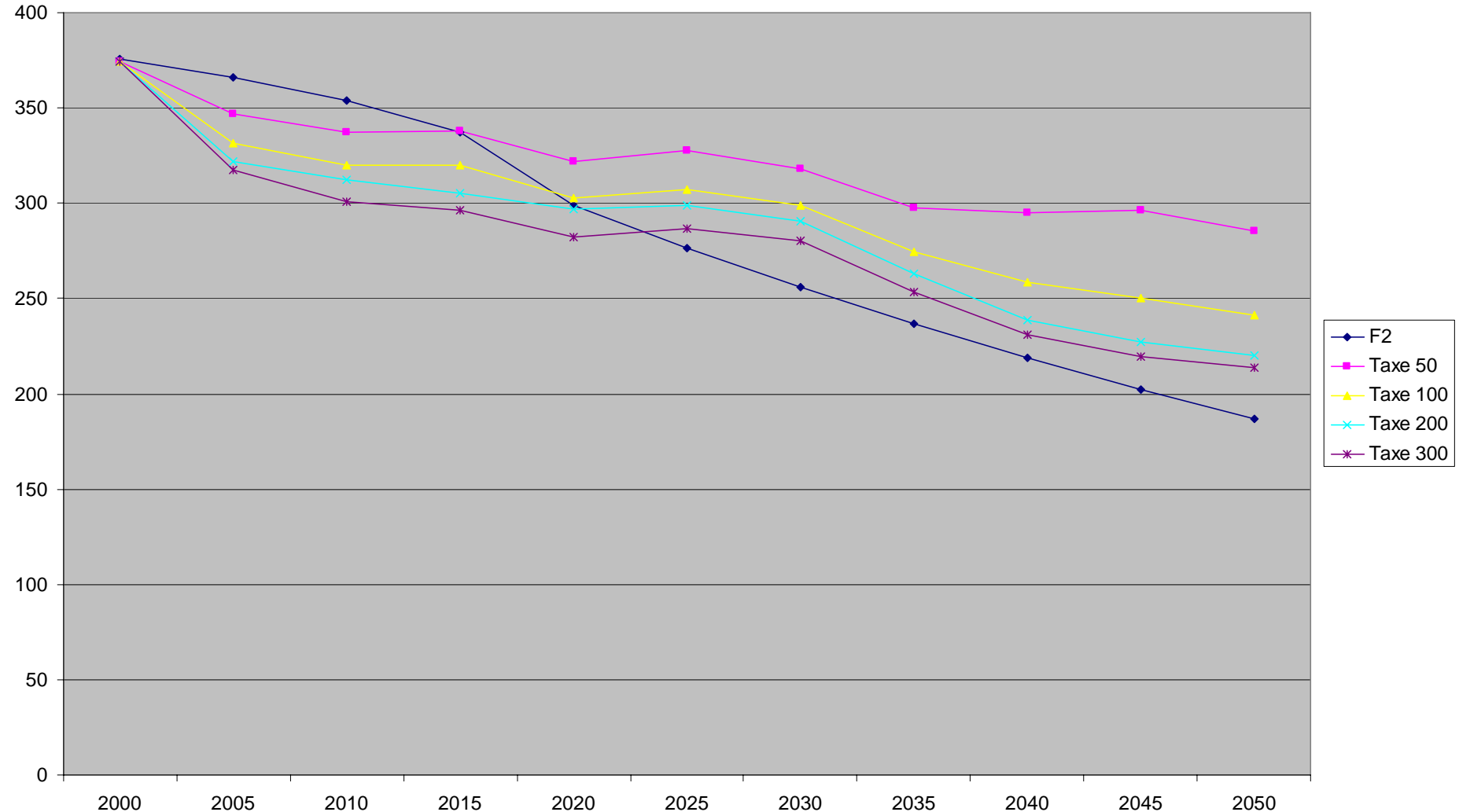
Low Carbon scenario (feasible nuclear) with CO₂ penalties

- CO₂ emissions with respect to CO₂ penalty levels

Penalty (€/t)/ Vol Total CO ₂ (Mt)	2000	2010	2020	2030	2040	2050
F2 (0)	368,4	351	299,2	255,81	218,72	187
50	368,4	337,7	325,5	321,3	300,9	291
100	368,4	320,45	303	304	265,8	252,9
200	368,4	312,01	293,0	296,5	244,9	229,3
300	368,4	301,08	278,6	285,57	237,84	224,2

Low Carbon scenario (feasible nuclear) with CO₂ penalties

■ CO₂ emissions with respect to CO₂ penalty levels



■ Focus on transportation

